HIGH RESOLUTION GIS MAPPING AND CURRENT STATUS OF THE TEN VIABLE POPULATIONS OF SHORT'S GOLDENROD (*SOLIDAGO SHORTII*–ASTERACEAE) IN KENTUCKY

Brent D. Smith

Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky 40475, U.S.A.

Andrew T. Denham

Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky 40475, U.S.A.
Current address: 2266 Ard Ridge Rd.
Nancy, Kentucky 42544 U.S.A.

James B. Beck

Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky 40475, U.S.A.
Current address: Department of Biology
Washington University
St. Louis, Missouri 63130-4899 U.S.A.

Patrick J. Calie[1]

Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky 40475, U.S.A.
pat.calie@eku.edu

ABSTRACT

Short's goldenrod (*Solidago shortii* Torr. & A. Gray) is an endemic species with a highly restricted distribution, the Kentucky populations occurring in and around the vicinity of Blue Licks in the northeastern portion of the state. The general occurrence of the species was first mapped in 1987, with several similar maps being published from 1989–2000. Due to changes in local land use practices the status of the populations has rapidly changed rendering these maps obsolete. A census of all populations was conducted and the precise topographic location and physical boundaries of each extant population was mapped using field reconnaissance techniques and GIS mapping technology. Between 1989 and 2003 four of the original populations were extirpated, eight declined in number of stems present, and one increased in both number of stems and area coverage.

RESUMEN

La "Espiga de oro de Short" (*Solidago shortii* Torr. & A. Gray) es una especie con poblaciones altamente restringidas en y a los alrededores de Blue Licks, al norteste de Kentucky. La distribución general de las poblaciones de esta especie fue cartografiada por primera vez en 1987 y varios mapas han sido publicados entre 1989-2000. Debido a cambios locales en el uso de tierra para cultivo, la distribución original de las poblaciones de la especie se han modificado en gran medida, y en consecuencia los mapas existentes están obsoletos. Un censo de todas las poblaciones, observaciones de campo, y técnicas del Sistema de Información Geográfica (SIG) han permitido la ubicación topográfica precisa y la delimitación física de cada población. De 1989 a 2003 cuatro de las poblaciones originales han desaparecido, ocho disminuyeron en número de tallos y una población aumentó en número de tallos y en área de cobertura

[1]Author for correspondence: Department of Biological Sciences, 235 Moore Science Bldg, 521 Lancaster Ave., Richmond, Kentucky 40475-3124, U.S.A. Ph: 859-622-1505; fax: 859-622-1399; e-mail: pat.calie@eku.edu

SIDA 21(2): 1121–1130. 2004

INTRODUCTION

Solidago shortii (Asteraceae) is listed as an Endangered Species in the Federal Register (Anonymous 1985). Charles Wilkens Short originally discovered specimens of the species growing on boulders at the Falls of the Ohio River in Jefferson County, Kentucky, in 1837. All remnants of those populations were either destroyed by inundation resulting from the construction of the McAlpine locks and dam to facilitate navigation on the Ohio River in 1925 (Buchele et al. 1989) or were extirpated in the latter half of the 19th century (Baskin et al. 2000). The species was "rediscovered" by E.L. Braun in 1939, in the vicinity of Blue Licks, KY (Braun 1941) (Fig. 1). The first map showing the spatial distribution of the Blue Licks populations was constructed in 1986 (Evans 1987). Several subsequent reports contained maps of similar resolution (e.g. Buchele et al. 1989), with a new population being noted in Baskin et al. (2000).

During the course of our field investigations from 1995-2003, we observed marked changes in the spatial size and occurrence of specific populations, due in part to local land-use practices and to local successional changes in several habitats. It became very clear that updated maps were needed to facilitate management practices involving this species.

This study was undertaken with two objectives in mind: 1) to develop higher resolution maps of each known Kentucky population of Short's goldenrod using Geographic Information Systems (GIS) cartographic technology; and 2) to update the status of each population first demarcated by Evans in 1987. Given the demonstrated utility of Geographic Information Systems technology in land use management (Longley et al. 1999) and species inventory applications (DeMers 1996), this application was a logical choice for developing accurate maps.

MATERIALS AND METHODS

Field Work-Population Census.—During the 2000 field season the boundary of each population first documented by Evans (1987) and Buchele et al. (1989) was defined through field surveys. Multiple transects through each population were established, dividing the population into parallel 3-meter-wide strips. The space between successive transects was then traversed, each individual *S. shortii* stem being counted. The majority of populations exhibit a linear rather than a polygonal distribution, which made this direct count approach technically feasible. This represents at best a minimal estimate, as undoubtedly some stems within the population boundaries escaped our detection, and some scattered plants do exist outside the demarcated boundaries.

Field Work-GPS Coordinates.—GPS Lat/Long coordinates, taken in the degrees/minutes/seconds format, were determined with a Magellan 2000 handheld GPS device at 50-meter intervals along the established perimeter of each population. Reference maps for each population were drawn in the field, using

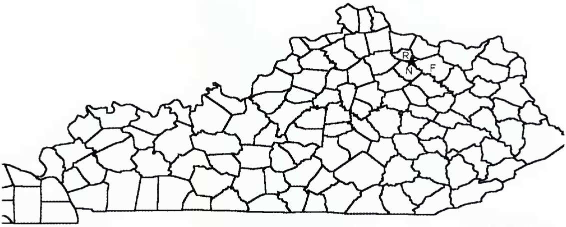

Fig. 1. Location of the populations of Short's goldenrod in Kentucky. The "star" indicated the approximate location of the majority of populations at the intersection of Fleming (F), Robertson (R), and Nicholas (N) counties.

measurements taken from local landmarks to orient field maps with aerial photographs and topographic maps (described below). Area estimates for each population were calculated from field measurements and combined with stem counts taken in 2001 to obtain density estimates for each population.

GIS Mapping.—An Event Theme using the GPS data points was created in ArcView 3.0. The X coordinate was set to Longitude, the Y coordinate to Latitude, and the Projection was set to Lambert Conformal Conic. Aerial and topographic images of the field research area were downloaded from the Kentucky Office of Geographic Information Systems (KYOGIS) website (ogis.state.ky.us/). The KYOGIS download included a file containing georeferencing information.

A Line Theme was created to show the plants' distribution. The plants' locations and their proximity to landmarks visible on the aerial photo were verified and corrected based on our field observations. Other data sets were combined with the images and population lines. For example, a State Highways theme and Counties theme from Environmental Systems Research Institute (ESRI) were added to show the locations of highways and county boundaries. Finally, we created the included maps (Fig. 2) using the ArcView Layout tool. All data and map files are available to appropriate scientific investigators and state and federal agencies upon request.

RESULTS

The ArcView system allows us to superimpose the GPS-derived data points for each population onto a number of high resolution cartographic interfaces, e.g., an aerial photograph (Fig. 2A) or a topographic map (Fig. 2B). Comparisons with earlier maps are not quantitative due to differences in cartographic methodologies. Likewise, exact comparisons of surface area coverage for each popu-

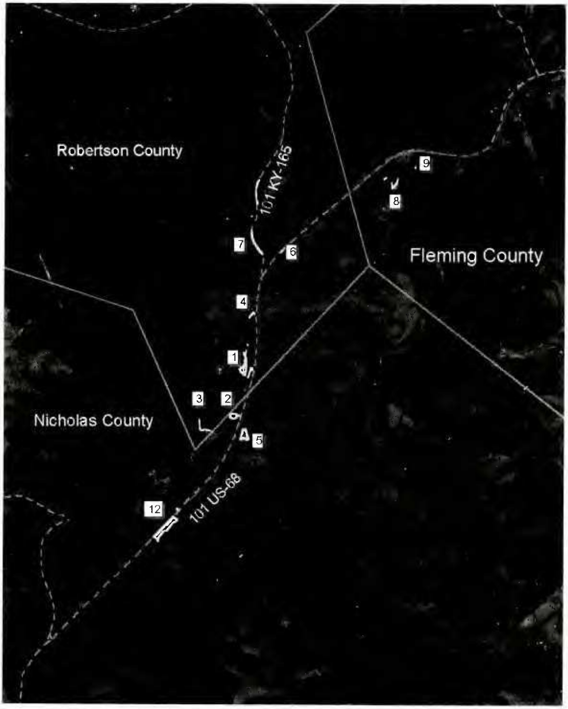

Fig. 2A. Example of a GIS-generated map showing the location of the known extant Kentucky populations of Short's goldenrod, with the exception of populations #11 and #15. Boxed numbering of populations follows Evans (1987). Solid white lines are county boundaries, dashed white lines are state and federal highways, the serpentine figure traversing the map is the Licking River, and population boundaries are shown in red. Only those populations found on properties in either state or federal agency ownership are shown.

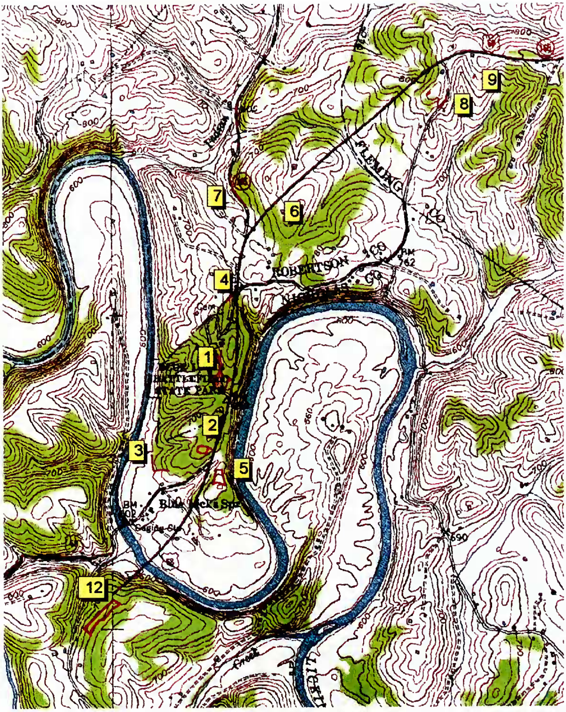

FIG. 2B. The identical shape file in figure 2A, now superimposed over a USGS topographic map.

lation relative to an earlier study (Buchele et al. 1989) are difficult due to differences in sampling techniques. However, we are confident that both sampling methodologies are of sufficient accuracy to allow for general comparisons. Two populations found on lands in private ownership (#11 and #15) are not shown on our maps to provide those populations with some measure of protection.

The census results, rather dramatic when compared to earlier stem counts, are summarized in Table 1. Based upon comparison with earlier stem counts and surface area estimates (Buchele et al. 1989) the populations cluster into the following categories.

Decline.—This is the status of populations #1–4, #7, #11 and #12, all having declined in stem numbers ranging from a 1.25-fold to 33-fold. Population #6 exhibits a larger fold decrease, now consisting of only one stem. We consider this population to be extirpated. A concomitant decrease in surface area is also seen in population #1–4, #7 and #8. While experiencing a slight decline in stem number (1.25-fold), population #12 has expanded its surface area by 13-fold. Census data for population #11 are not available for 2002, as we were unable to obtain permission from the private property owner to examine this site. GIS data were obtained for this population along a bordering road, and mapped from prior field observations.

Extirpated.—Population #6 occurs along a highway right-of-way, and is a remnant of a once larger population that was intentionally destroyed by a local landowner. There is now a single stem remaining. The original population #10 (Evans 1987) was destroyed by a local landowner (Mr. Allison, pers. comm.). We discovered a remnant set of eight plants in 1998, ca. 100 meters east of the original locality. This set is now extirpated due to local successional changes, e.g., increased canopy cover from arborescent species (primarily *Quercus* spp.).

Increase.—Population #5 is the only population that has increased in stem number, from 530 in 1989 to an estimated 3,488 in 2001. This is accompanied by an increase in coverage area from 870 m^2 in 1989 to 5,380 m^2 in 2001. This is now the largest Kentucky population of Short's goldenrod in terms of both area and stem number.

Doubtful reports.—Population #14, located on private property (the Kingsolver farm near Blue Licks Battlefield State Park) has been of doubtful determination since its "discovery". There are no voucher specimens from this site, and repeated efforts by the authors in 1998 and 1999 and by D. White (Kentucky State Nature Preserves Commission, pers. comm.) to locate *S. shortii* plants met with failure. This population, if ever extant, is now extirpated

Recently discovered population.—Population #15 was discovered by Mr. Nick Drozda of the KSNPC during a survey of a bison trace (trail) in 1998. This population was revisited in 2003 and found to have increased in number of stems and distribution.

Table 1. Summary of population census and area of coverage of all known verified populations of Short's goldenrod in Kentucky. Data from 1989 are those of Buchele et al. (1989), from 2001–2003 are from this study. The numbering of populations #1–13 is that of Evans (1987). Population #14 was designated and first mapped by Baskin et al. (2001), and #15 is the recent discovery by N. Drozda. The "First Report" entry refers to the earliest notation in status records maintained by the USFWS and provided by D. White of the KSNPC. KSNPC = Kentucky State Nature Preserves Commission; P = private ownership; KSPC = Kentucky State Parks Commission; KHC = Kentucky Highway Commission; ROW = Right-of-Way; USFWS = United States Fish and Wildlife Service. **extirpated* = population consisting of 1 plant, but in essence extirpated; **14 = dubious report; ***15 = stem number estimate provided by N. Drozda (pers. comm.).

Population #	Stem # 1989/2001	Fold increase/ decrease	Area m2 1989/2002	Fold increase/ decrease	Density (# stems/m2)	Ownership	First Report
1	42,000 / 2,549	16-fold decrease	4,600 / 3,027	1.5-fold decrease	9.13 / 0.842	KSNPC/KSPC	1936
2	10,150 / 573	18-fold decrease	12,840 / 1,367	9.4-fold decrease	0.790 / 0.419	KSPC	1983
3	3,500 / 193	18-fold decrease	4,500 / 300	15-fold decrease	0.778 / 0.642	P	1987
4	1,400 / 42	33-fold decrease	1,290 / 193	7-fold decrease	1.08 / 0.217	KSNPC / KSPC	1936 (?)
5	530 / 3,488	7-fold increase	870 / 5,380	6-fold increase	0.609 / 0.648	KSNPC	1983
6	2,100 / 10 (00), 1 (02)	**extirpated*	515 / 1	NA	NA	P / KDOT (ROW)	1986
7	6,300 / 1,000	6-fold decrease	6,230 / 524	12-fold decrease	1.01 / 1.91	KDOT (ROW)	1957
8	1,780 / 672	3-fold decrease	2,570 / 766	3-fold decrease	0.692 / 0.877	KSNPC	1934
9	640/<25 (00), 3 (02)	**extirpated*	2,485 / 1	NA	NA	P (ROW)	1987
10	240 / 13 (00), 0 (02)	*extirpated*	15 / 0	NA	16.0 / 0	P / KDOT (ROW)	1985
11	2,500 / 800	3-fold decrease	265 / NA	NA	9.43 / NA	P	1985
12	2,300 / 1,846	1.25-fold decrease	390 / 4,877	13-fold increase	5.89 / 0.378	USFWS (ROW)	1939
13	180 / 0	*extirpated*	Feb-00	NA	90.0 / 0	P	1987
**14	15-20(?) / 0	*extirpated(?)*	NA	NA	NA	P	1989
***15	NA / 100 (03)	*NA*	NA/120	NA	NA / 0.83	P	1998

DISCUSSION

Given the state of mapping technology in 1987 (and the passage of time) it is not surprising that maps derived through GIS applications are different from the original maps. What is of particular note is the general numeric decline in all but one population (#5) of *S. shortii*. Populations #1, 2, and 4 have been within the jurisdiction of the Kentucky State Parks Commission during this period of comparison, yet all three have suffered massive decline. An unequivocal cause for the decline of these three and/or any other populations under protection (i.e., populations #5 and 8, under the jurisdiction of the KSNPC, and population #12, under the USFWS) is not clear.

The spatial distribution patterns of the populations fall into two categories. The first we term "linear" (populations #1, 3–4, 6–9, 11 and 12). Several of these populations occur along either power line or highway rights-of-way (Table 1), but others occur in what appears to be uninterrupted habitat (e.g. #4) conforming to a linear pattern. This could be due to localized edaphic conditions, as the preferred habitat is one with shallow soils. The second category we refer to as "polygonal" (populations #2 and #5). These habitats are continuous areas uninterrupted by roads. The plants, however, are distributed discontinuously throughout the mapped area, the perimeter of the populations assuming an irregular geometric outline. The precise reasons for this difference in spatial distribution patterns is at present unknown but could be due to subterranean factors, e.g., rock shields underlying shallow soils and providing an unsuitable habitat for competing species. Alternatively, the plants' distribution could be due to seed dispersal patterns of those specific populations. At present both of these postulates remain untested.

The results of the stem count comparison are dramatic. Numbers of stems has decreased since 1989 for all observed populations except #5. This population exists in an old field that is currently under the management and ownership of the Kentucky State Nature Preserves Commission. The results of the area estimates are equally dramatic, since all of the observed populations except for #5 have decreased in area since 1989. Population #1 has experienced the most marked decline, most likely due to improper management and increased development and use of park recreation facilities by visitors. This population is now dissected into several distinct groups, each following either a road or a power line right-of-way or a former bison trace remnant. The glade area within the park where the plants were previously observed in abundance is now populated primarily by *S. nemoralis*. A similar situation exists in population #2. The impact of *S. nemoralis* on the long-term persistence of *S. shortii* is not known, although we have observed a steady decline in these two populations (Table 1).

Three populations have been extirpated, one by natural means and two by human intervention. Population #13 occurred in an open field and consisted of 180 stems in 1989 (Buchele et al. 1989). The field was subjected to mowing in the early years of the 1990s, but in the latter half of the decade the field was not cultivated. Competition from non-native grasses (e.g, *Festuca*) and forbs (e.g., *Lespedeza*) have contributed to the loss of this population. Population #6 grew in an actively grazed pasture and was removed by the landowner in 1988 by bulldozing the habitat (USFWS records and D. White, pers. comm.). In discussions with the local landowner it was revealed that population #10 was eliminated through extensive mowing of caulescent stems and the deposition of concrete debris on the persistent rosettes, beginning prior to 1995. Population #11 occurs along a woodland edge and appeared rather stable over the period of this study.

The status of a questionable population has also been resolved. Population #14 was first cited in Baskin et al. (2000). We were unable to locate plants in the field during 1998 and 1999, and there was confusion regarding the accuracy of the original species determination (D. White, pers. comm.). Records maintained by the USFWS indicated ca.15–20 stems of "Short's goldenrod" in 1989, but none was found in either 1997 or 1998. Independent efforts by D. White (pers. comm.) were also unsuccessful. If this population of Short's goldenrod ever existed, it is clear that it is now extirpated.

In 2000, a new population was discovered by N. Drozda of the KSNPC along a former bison trace (trail) in Fleming County. This population consisted of ca.25 stems, and the plants were described as "depauperate" (USFWS records). The population, designated as #15 in Table 1, persisted into 2003 and now consists of ca. 100 stems concentrated along the bison trace with a few individuals scattered in the adjacent woods.

In 1995 seven "clumps" of cultivated *S. shortii* (originally obtained from a Blue Licks population) were planted on the Indiana shoreline of the Ohio River, across from the type locality at the Falls of the Ohio River in an effort to reintroduce the species into suitable riparian habitat (Homoya 1996). These plants were lost in the following year due to increased water flow from winter runoff (D. White, pers. comm.). A recent report describes a population of Short's goldenrod in Indiana (www.in.gov/dnr/public/novdec01/news1.htm). This is the first verified record of Short's goldenrod outside of Kentucky (a voucher specimen has been deposited at MOBOT), the site occurring within a former migration pattern of the extinct eastern woodland bison (*Bison bison* L.). This could represent a very old population that has been genetically isolated from the Kentucky populations for perhaps several centuries. Alternatively, this population could consist of escaped colonizers from the 1995 effort to reintroduce the plants in Indiana, as the newly discovered population is ca. 50 nautical miles downstream from the attempted reintroduction. Genetic analyses of samples from both the Kentucky and Indiana populations are now underway in an effort to resolve this issue.

ACKNOWLEDGMENTS

Appreciation is extended to the Wilderness Road Girl Scout Council Troop #1265 for their mapping of population #4, and to Bruce Davis and the GIS Map Laboratory of Eastern Kentucky University for assistance with GIS software and map generation. Funding in support of field and computational activities was obtained through a Sigma Xi Grant-in-Aid of Research (JBB), through contracts #20379 and #99161405 from the Kentucky State Nature Preserves Commission and the US Fish and Wildlife Service, two EKU Faculty Research Awards and NIH/NCRR Award #P20 RR16481-S1 (PJC). Discussions with Marc Evans and Deborah White, and the field assistance of Tiffany Carpenter and Christina Shackleford are gratefully acknowledged. Nick Drozda escorted PC to population #15 and provided critical background information. The comments and reviews of Moriah Beck and Rob Naczi on the manuscript, and assistance from Sara Fuentes and Lupita Sanchez with Spanish translation are appreciated.

REFERENCES

Anonymous. 1985. Listing of threatened and endangered species. Fed. Reg. 50:36085–36089.

Baskin, J.M, J.L. Walck, C.C. Baskin, and D.E. Buchele. 2000. Ecology and conservation of the endangered plant species *Solidago shortii* (Asteraceae). Native Pl. J. 1:35–41.

Beck, J.B., R.F.C Naczi, and P.J. Calie. 2001. Insights into the species delineation and population structure of *Solidago shortii* (Asteraceae) through morphometric analysis. Rhodora 103:151–171.

Buchele, D.E., J.M. Baskin, C.C. Baskin. 1989. Ecology of the endangered species *Solidago shortii* I. Geography, populations and physical habitat. Bull. Torrey Bot. Club 116:344–355.

Braun, E.L. 1941. A new locality for *Solidago shortii*. Rhodora 43:484.

DeMers, T. 1996. Remote sensing and geographical information systems: Spatial technologies for preserving phytodiversity. In: T.F. Stuessy and S.H. Sohmer, eds. Sampling the green world. Innovative concepts of collection, preservation, and storage of plant diversity. Pp. 125–139.

Evans, M. 1987. Short's goldenrod recovery plan. Unpublished Technical Agency Draft. USFWS, Southeast Region, Atlanta, GA.

Homoya, M. 1996. The return of Short's goldenrod. Endang. Spec. Tech. Bull. 21:24–25.

Longley, P.A., M.F. Goodchild, D.J. Maguire, and D.W. Rhind (eds.). 1999. Geographic Information Systems: Principles, Techniques, Applications and Management. Second ed. John Wiley and Sons, New York.